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BOSTON SOCIETY
OF
CIVIL ENGINEERS

OCTOBER, 1930

Featuring

**Exposed Surfaces of Concrete
and their Protection**

Ready-mixed Concrete

The Port of Hamburg



Vol. XVII

No. 8

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EXPOSED SURFACES OF CONCRETE AND THEIR PROTECTION

By ANGUS B. MACMILLAN*

(Presented before the Designers Section, Boston Society of Civil Engineers, December 11, 1929)

THERE are many opinions in regard to the causes underlying the breakdown of exposed concrete surfaces, but the primary one is that water is an important factor. Water used excessively in the concrete mix will result in a concrete more porous and weaker than can be expected from the same materials if properly combined with due respect to the water cement ratio. Water may act on the finished structure in a number of ways which are detrimental. The condition of perviousness which permits moisture to gain access to the concrete mass may be due to a lack of density in the concrete mixture or the presence of joints or cracks. Lack of density in the mix may usually be accounted for by (a) poor proportions, (b) poor aggregates, (c) insufficient mixing, (d) an excessive amount of water in the mix, (e) improper handling, and (g) improper curing. Joints are a necessary evil, but they should be so constructed and located that they do not readily admit water. Cracks may result from (a) external violence, (b) initial shrinkage and internal stress, and (c) from volumetric changes because of constantly changing conditions of temperature and moisture.

If water gains access to the concrete mass it may dissolve some of the hydrated cement compounds. This action may be hastened by the presence of sulphur or carbon compounds in solution. It may become frozen in the pores, forming crystals whose expansion will gradually cause a breakdown of the affected parts, or it may, upon evaporation from the surface, leave dissolved salts in crystalline form to act in a manner similar to that of the ice crystals. When steel reinforcement is present in the concrete it is evident that if water containing free oxygen

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can gain access to the steel the expansion of the oxides formed will disrupt the surrounding concrete. There is still another way in which water seems to play a very definite part.

The presence of very minute cracks on concrete surfaces is not unusual. In some ways they are similar to the checking of timber. Concrete on drying out shrinks — the richer the concrete mixture the greater the shrinkage. As the outer skin dries more rapidly than the interior of the mass a condition of tension is created, and as concrete is not particularly strong in tension it breaks down or crazes.

In Bulletin No. 7, by W. K. Hatt and R. E. Mills, issued by Perdue University, the following statement is made: "It appears that surface checks or crazes develop more slowly in concrete exposed under uniform conditions, as in the air of a shed, than in concrete exposed to the weather." These cracks are usually very fine and quite shallow. At the beginning they are of little importance. Constant volumetric changes, however, as a result of changes in temperature, or, more particularly, as a result of variations of moisture, affect the exposed surfaces more than the interior of the mass, and widen and deepen these cracks to a point where some of them may eventually become important. If they enlarge sufficiently so that water can gain access to the steel through them, or so that intrained water can freeze in them, the expansive forces of oxidation will continue to enlarge them. The increased growth of these cracks may also be fostered by a condition of internal stress which exists between the steel reinforcement and the concrete. These stresses may be of considerable magnitude.

Fortunately concrete, during the early stages at least, is somewhat plastic and seems to flow and relieve itself under stress. It is therefore probable that such adjustment takes place, greatly reducing the theoretical stresses. The apparent absence of severe cracking on the tension side of properly designed interior beams and slabs supports this belief. However, it must be assumed that the readjustment which takes place is not perfect, and that some internal stress still exists, and that if so, in combination with variations of moisture and temperature, it will increase the tendency of occasional craze cracks to penetrate to the steel, and perhaps beyond the steel towards the neutral axis. As the strains in the concrete from this source are unequally distributed, being greater immediately adjacent to the steel, it may be concluded that the presence of large concentrations of steel very close to the concrete surface is undesirable. It may also be concluded that round bars would present less obstruction to the flow of concrete than square bars, and are therefore desirable, and the question may be raised whether plain bars might not

have some merit over deformed bars in this case. Small round bars well distributed for reinforcing exposed surfaces would, in general, seem desirable. They should in no instance be nearer to the surface than one and one-half inches, nor in general, for economic reasons, would it seem desirable that the embedment be greater than two inches.

FIRST MANIFESTATIONS OF DISINTEGRATION

Surface deterioration usually proceeds quite slowly. Generally the first manifestation which would attract attention is the appearance of streaks of rust on the surface, or possibly the breaking off of a fragment of the edge of a lintel or column. On examination it will usually be found that the concrete at the rusty places is cracked and loose. If this is chipped away, exposing the reinforcement, the exposed bar or bars are generally heavily corroded. This condition inevitably results in a weakening of the bond of the steel to the concrete, and in a distinct reduction in the area of the steel. Of course this condition should not be allowed to progress to this stage, but if it has, steps should be taken at once to prevent further disintegration. Fortunately, the needed preventive measures are not prohibitive in cost.

STEPS TO DELAY DISINTEGRATION

Before attempting to describe methods for repairing concrete which has begun to decay, attention will be directed toward some of the steps which should be taken in order to delay the beginning of apparent disintegration as long as possible.

One of the first requirements is an impervious concrete. While it is doubtful if an absolutely impervious concrete can be produced, it is desirable that this condition should be approached as nearly as possible. In order to do so certain fundamentals must be adhered to.

The aggregates must be clean, durable and well graded.

The proportions of the mixture must be such that each particle is embedded in and surrounded by an impervious cement matrix. This must be based on a proper water cement ratio.

Mixing shall be by means of an approved batch mixer, and shall be continued for not less than one minute from the final deposition of all the ingredients of the batch into the mixer. Constant checking of the consistency of the mixture by means of slump tests should be mandatory. In making these tests it must be understood that a consistency which is too stiff at the end of one-half a minute of mixing may give too great a slump at the end of a minute. In other words, long-continued mixing increases workability.

The mixed concrete must be transported to the place where it is to be deposited by devices which do not cause a segregation of the coarse and fine particles or require excessive amounts of water in order to permit the concrete to flow.

The concrete must not be deposited in one place and allowed to spread out in a wedge to a thin edge in any direction, but should be carried up a uniform thickness at all points at all times.

The deposited concrete should be rodded sufficiently to (a) settle it as much as possible and (b) make sure that the steel is thoroughly surrounded. It should not be rodded in such a manner as to cause the segregation of areas of coarse aggregate at the surface, or so as to bring excessive water and fine aggregates and cement to the top.

The forms into which the concrete is deposited must be tight. The presence of cracks in the forms permits some of the smaller particles to leak away, leaving the coarser aggregates and a more porous concrete immediately adjacent to the cracks.

After deposition the concrete must be properly cured. This means the regulation of heat and moisture so that the concrete will not freeze in cold weather or dry out too rapidly under any conditions. It must also be protected from excessive external loading for a reasonable length of time.

The necessity of joints has been briefly touched upon, but the probability of trouble from them can be reduced by taking suitable precautions. The joint wherever occurring should be carefully freed from adhering dirt or loose concrete and picked to expose a clean fresh surface. This surface should be brushed with a mixture of cement and water of about the consistency of cream. Before the grout has dried out or set a layer of cement mortar slightly richer than the mortar of the concrete mix should be placed upon or against the old concrete surface and followed immediately by the new concrete. As an additional precaution, when the joints are in lintel beams, or are vertical joints in walls on the outside of the building, it is frequently desirable to add extra reinforcement in the form of small bars well distributed across the joint. The amount should not be less than one-half of one per cent. They should extend at least forty diameters on either side of the joint, and should not be closer to the exposed surfaces than one and one-half inches.

PROTECTIVE MEASURES

When the various measures recommended for obtaining good concrete have been taken, others of a protective nature will naturally follow, which, while having the same end in view, secure the results in different

ways. One seeks to increase the density of the concrete by the addition of finely divided inert materials of which "Celite" is an excellent example; another, by the use of a "water repellant" such as "Aridol." Still another method, and the one most favored by the writer, is to seal the surface with an elastic varnish and protect the varnish with appropriate paint. This treatment would seem to be the more logical, as it should tend to bridge any small cracks and prevent the entrance of water into them. This may not be true of the other remedies. Of course paint will require renewal from time to time.

Where no deterioration has taken place, and protection against such a possibility is desired, painting is indicated. Should the surface of the structure have suffered damage, a certain amount of replacement, as well as protection, will evidently be required.

COST OF REPAIRING A TYPICAL REINFORCED CONCRETE BUILDING

During the month of April, 1926, the Aberthaw Company was asked to recommend the measures that should be taken to repair the surface of a concrete mill building in the vicinity of Boston. As neither the architects nor the builder were known to the occupants of the building, detailed drawings of the structural members were not available. The city records indicated that it was built about the year 1913. When examined in 1926 the exterior concrete work looked rather bad. The corners of a number of columns had broken off, exposing the vertical reinforcing, the outer edges of many of the lintels were gone, and patches of concrete to the depth of approximately an inch had fallen off, leaving the steel bare. Many stirrups which apparently were fabricated from thin flat bars were sticking out, so badly corroded in most cases that they broke off when bent into place. The lower leg of the structural steel sashes had been allowed to project into the concrete sills when they were cast. As a result moisture had found its way into the joint, and the rusting of the sash bar which resulted had split many of the window sills. Probably frost assisted the action. The general appearance was very bad, no effort whatever apparently having been made to keep even the steel sash or the outside fire escape properly painted, so all exposed steel work was more or less rusted.

The interior of the building was in excellent condition and showed no signs of deterioration; in fact, even the surfaces of the granolithic floors, despite thirteen years of constant wear from trucking, were good.

The building itself was about 100 feet wide by 120 feet deep, and nine stories, or approximately 115 feet, high. The total surface area,

including windows, was about 50,000 square feet. Of this the window area formed about one-third.

The Aberthaw Company recommended that the work be carried out in accordance with the standard specifications given later in this paper. The owners, however, decided not to apply the varnish coat and not to replace the sills that were split, merely calking the crack between the sill and the sash.

All work was done from sling stages attached to the cornice. A small air compressor was used for removing areas of loose concrete and for cleaning the surfaces to be patched. As soon as a patch was in place it was covered with burlap and the burlap kept wet for ten days.

The work was performed during the months of June, July and August. The total cost of this work, including the contractor's profit, was \$6,048 in round figures, or approximately 12 cents per square foot of gross surface area. On this basis the deterioration of the exterior cost the owners about one cent per square foot per year.

The paint used was two coats of Briggs Maroney's Concrete Coater for the concrete, and two coats of Briggs Maroney's Steel Guard paint for all steel work. At the present time both patching and paint are apparently in good condition and no further trouble seems to have developed.

Specifications covering the methods which have been developed and used by the Aberthaw Company for patching and painting follow. Undoubtedly modifications may be made if it is desired to experiment, and other paints or varnishes may be used.

Specifications for Patching

1. The entire surface of the building shall be examined minutely and any loose concrete removed.

2. Steel that is exposed shall be carefully freed from rust by wire brushing, and if close to the surface, that is, within an inch of the exposed face, shall be painted with an asphalt paint.

3. Any loose steel shall be fastened into place by means of anchor bolts or other devices.

4. Mortar made from one part Portland cement mixed with two parts of sharp, clean sand carefully graded in size from a three-sixteenths inch mesh down, so as to insure maximum density, shall be prepared. The amount of water used shall be just enough to give a fairly stiff mortar at the end of two minutes' mixing. This mortar shall be held for not less than five hours before use, the set being prevented by stirring in the meantime as required. The reason for holding the mix is

simply to get rid as far as possible of the violent expansion and contraction which take place after hydration, and which tend to prevent the patch from adhering effectively.

5. Those parts of the work which require patching shall be cleaned and roughened so as to expose a fresh surface, and shall be wet down thoroughly until they are saturated with water.

6. The mortar previously prepared shall be applied with a trowel in thin layers and carefully pushed into place until the surface has been built out to the thickness required to conform to the rest of the work.

(a) It is sometimes considered desirable to paint the surface to be patched with a Portland cement grout just before applying the plaster.

(b) If a large amount of patching is required, the use of a cement gun may be justified. Usually this is not the case.

7. All patching shall be done in warm, clear weather.

8. All patches shall be covered with burlap and kept wet for a week or ten days.

9. When the patches are thoroughly set and dried the entire surface shall be painted to prevent the further action of the elements.

Specifications for Painting

1. All concrete surfaces to be treated shall be given a coat of the following mixture: To each gallon of water add four pounds of zinc sulphate and two ounces of ultramarine blue; mix, and apply with a brush. This application is made to neutralize any lime on the surface which if present might attack the oil in the paint or varnish. The ultramarine blue is added solely to show what areas have been treated.

2. When the preparatory treatment has dried, paint the building with one coat of long china wood oil and ester gum. This is to seal up the pores and make the surface watertight.

3. Over this apply two coats of titanium oxide and china wood oil paint of suitable formula, colored as required, to protect the under coat.

This completes the operation.

Sometimes, in order to economize, the under coat application has been omitted.

The results obtained where the under coat has been omitted have been good, but as all flat paints are more or less porous the use of the priming coat is doubtless an improvement that is worth while.

Repainting will, of course, be necessary at intervals.

Painting should preferably be done in warm, dry weather, and, although it may be needless to state, *all surface dust should be removed* before painting.

READY-MIXED CONCRETE

By MILES N. CLAIR,* MEMBER, BOSTON SOCIETY OF CIVIL ENGINEERS

(Presented before the Designers Section of the Boston Society of Civil Engineers, February 5, 1930)

UNTIL comparatively recently concrete has been almost entirely a job-made structural material. Variations in materials, methods and exposure naturally have resulted in concrete of variable quality. On the usual job, involving but a few hundred cubic yards of concrete, the concrete has been produced by the concrete foreman without any supervision or directions. He was presumably an experienced concrete man, and as long as he kept up to the progress schedule, and did not overrun on cement, nor produce too much honeycomb, very little attention was given to how he proportioned the concrete. It is true that the architect or engineer might have a representative check the barrows or measuring hoppers, but in general the concrete foreman, with "his twenty years" of experience, did just about as he wanted. It is surprising how much good concrete has been produced by this method, and not at all surprising how much more poor concrete. The overconfidence of the architect and engineer, however, in their knowledge of that "perfect material-concrete," is to blame for the unsatisfactory durability of concrete structures, and not the concrete foreman. They had assumed that the making of concrete is a very simple matter, but the lack of durability of some of the earlier structures has brought about a critical examination of concrete from all angles, — in the laboratory, office and field. The result of this study or re-study up to the present has been that a good many previous ideas have been scrapped and a few definite laws established. One thing that has become apparent from this study is that to produce uniformly durable concrete there must be used durable, clean materials, combined with a constant ratio of water to cement, in order to produce a mix which is easy to place, and yet in which there is not so much water as to allow segregation of the components, and then the concrete properly cured or protected. If the materials change, then the quantities must be changed if uniform quality concrete is to be produced. This is true, whether

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quality is measured by the compressive strength, the cement content, the permeability, or other characteristics. The application of these principles involves some difficulties, for to maintain a constant ratio of water volume to cement volume the moisture content of the aggregates must be known definitely as well as the quantity of water added; also as the characteristics of the aggregates change the change in voids should be known where it is desirable to keep the cement content a constant. Accuracy of measurements is important, and this means the use of methods that allow corrections to be readily made for the changes in the materials. Weighing appears to offer the best solution to this demand.

TESTING AND CONTROL

It must be apparent that the usual concrete foreman is not capable of making the concrete in strict agreement with the above principles without technical assistance. Such assistance can be provided on very large projects, and it was on such projects that the first attempts at control of quality were made. No large job force today would be complete without the testing, control or concrete engineer. The cost of the entire control, including two or three testing engineers and a complete field laboratory, may not exceed five cents per cubic yard; and this cost will be much more than repaid by the increased quality of the concrete, as well as by the actual saving in cement. On an ordinary concrete project, similar control would cost from one to two dollars per yard of concrete. The use of even partial control is expensive, and there is no great mystery, therefore, in the fact that control has not been adopted on small jobs. The resident engineer, or architects' superintendent, now gives more attention to the concrete than previously; but he cannot give it the necessary time to assure uniform concrete.

An organization producing concrete on a large scale, such as is essentially the condition on a great dam or concrete road project, would be an ideal source of concrete of uniform quality, as they could well afford to distribute the cost of control over many jobs. About ten years ago the production of ready-mixed concrete for general distribution was started in Philadelphia. Now there are one or more plants in all of the larger cities of this country ready to deliver concrete of any desired characteristics, in any quantity, anywhere, at any time. The purpose of this paper is to describe briefly the several systems under which ready-mixed concrete is now being produced, to indicate certain advantages and disadvantages of the different systems, and to describe some of the precautions to be taken in using such concrete.

SYSTEMS USED IN PRODUCING READY-MIXED CONCRETE

Ready-mixed concrete is produced today by one of the following systems:

1. The central plant mixed system.
2. The central plant proportioned truck-mixed system.
3. The central plant proportioned job-mixed system.

The central mixing plant system was the first in use, and is still most used, frequently in combination with some type of truck mixer. The third, or central plant proportioned job-mixed system, has not been used to any great extent in the ready-mixed concrete field. All of these systems require the establishment, at one or more places, of a central plant. This plant, for the central mixing system, must be in all details a complete concrete plant similar to that used on projects involving thousands of yards of concrete. The usual central mixing plant contains overhead storage bins for aggregates, a larger outside ground storage, storage for cement which is usually received in bulk form, weigh batchers for measuring the materials, one or two concrete mixers, and truck-loading apparatus. The usual central batching plant contains the same equipment as the usual central mixing plant, except that there is no concrete mixer. Many of the central mixing plants are arranged to deliver the materials after weighing into a truck mixer, if desirable.

The operating procedure in a central mixing plant is essentially that of any job concrete plant. The materials are measured, admitted to the mixer, mixed the usual length of time, and then dumped. The departure from the usual job procedure comes at this point, for the concrete is not conveyed directly to place in the forms, at the most a few hundred feet away, but must be conveyed to anything from a few feet to fifteen miles away. The vehicles used for transporting the mixed concrete for these distances range from the ordinary flat-bottom truck, such as is employed for sand and gravel hauling, to the elaborate agitating trucks which have some mixing action. The Blaw-Knox Agitating Truck consists of an open half cylinder with a longitudinal shaft to which arms are attached. This shaft is driven by a take-off from the truck motor, and thus some agitation can be given to the concrete during transportation. The removal of the concrete from this truck can be facilitated by lifting the front end of the body in a manner similar to that used on coal trucks. The Clinton Agitating Truck consists of a closed steel drum

mounted on a truck chassis, with an auxiliary motor to rotate the drum. The concrete is admitted to the drum from an opening on the side which is then closed. The discharge is through an opening in the end. The agitation of the concrete results from the rotation of the drum only, as there are no paddles or blades in the drum. Discharge is facilitated by lifting the front end of the drum in the same manner as for the Blaw-Knox truck. The LeBland-Schlacht Agitating body (Tru-Batch type) consists of a steel drum with its longitudinal axis transverse to the length of the truck. Agitation is provided by rotation, and the concrete is charged and discharged through the same opening in the side of the cylinder.

There are also several semi-agitating type bodies in use which produce a mixing action of the concrete during discharge. The Bartlett-Snow Ready-Mix Body is of the end dump type, with the sides made of movable plates. The sides are brought together at the bottom, forming a "V," and the concrete loaded and carried to the job. When ready to discharge, the sides are moved back to the vertical position by means of a hand crank. The body is then tilted similar to the procedure with the other types of trucks in order to aid the discharge of the concrete. The Hug Redi-Mix Body consists of a body with the upper part separate from the lower part. As the body is tilted to dump from the rear the upper section separates from the lower section which acts as a chute. There is a baffle cross plate near the center of the body which aids re-mixing, as the concrete flows over it in discharging.

There is another type of body in use which is non-agitating, but which is better than the ordinary flat-bottom truck. This is the bathtub body put out by the Wood Hydraulic Hoist & Body Company. The curved end and sides help to eliminate sticking of the concrete to the body.

Experience has shown that the non-agitating type of truck cannot be used for the transportation of concrete of the consistency desirable for reinforced concrete buildings for any length of haul over fifteen minutes without considerable segregation and possibly loss of ingredients. It has been found possible, however, to transport concrete of a dry mix such as is used in road work for over one hour without trouble in such trucks. It is suggested that the transportation of concrete in ordinary flat-bottom or non-agitating trucks should not be allowed where the consistency as measured by the slump is in excess of two inches. Centrally mixed concrete of a consistency such as is proper for ordinary building work should never be transported in any but agitating type trucks. The limit on the time of transportation will depend on the surrounding weather conditions, the mix, and the characteristics of the

materials. Sufficient tests have been made to show that the effect of varying the interval between the time of mixing and the time of placing, as long as the mix remains workable, is to decrease the consistency without any deleterious effect on the strength. These tests have shown that concrete after three hours and more of transportation in agitating trucks had a higher strength than the same concrete immediately after mixing.

Although there is not much question but that the compressive strength of the concrete is not adversely affected for reasonable periods of agitation, the effect of this long lapse between mixing and final placing on shrinkage, durability and other properties of the concrete is not known. Indications from prehydration tests are that this long agitation should be beneficial in reducing the shrinkage of the concrete, but definite information from carefully conducted tests is very much needed. Anything that will reduce shrinkage and consequent crazing, or other cracks, should help to increase the durability of the concrete, but here again definite information is needed. Taking all facts into consideration, it is recommended that, in general, a limit of one hour be placed on the time elapsed between the mixing and placing of centrally mixed concrete, and that in any case the interval shall not be so great as to cause the concrete to become unworkable or partly set. The partly set condition can be determined by inspection. Such concrete becomes mealy or short, that is, it breaks apart in chunks on mixing rather than flows.

The central batching plant truck-mixing system, as was stated previously, has a central plant similar to that used for the central plant mixed concrete, except that there is no mixer. The aggregates and the cement are proportioned and loaded into the truck mixer, and the water is measured and put into a tank or the truck mixer. On the way to the job, or after reaching the job, the water is admitted and the mixing started. There are a number of truck mixers in use, and probably the most used is the Paris Transit Mixer type and its modifications. This consists of a bottle-shaped steel cylinder mounted on a truck chassis. The aggregates are admitted at the neck end of the truck, and the concrete is also discharged from this opening. The water is admitted to the aggregates and cement from the truck tank through a perforated pipe running along the longitudinal axis of the truck. The inside of the drum is fitted with blades, similar to those in the usual concrete mixer, and the concrete is mixed by the rotation of the drum. The opening at the end of the drum is closed during mixing and transportation. The discharge of the materials is facilitated by a rotation of the drum and tilting. An auxiliary tank is carried with these trucks to supply water for flushing out the body as soon as the batch has been discharged. The

Jaeger Combination Body is similar to the Transit Mixer except that the blades on the inside have more of a screw action in moving the materials. The Barrymore Truck Mixer is one of the first types developed, and is essentially the same as the Blaw-Knox Agitating Body, except that it carries water tanks for the mixing when and where desired. There has also been proposed recently, and I understand will be in commercial use shortly, a truck mixer that keeps the cement separate from the aggregates until mixing is to be started.

The truck-mixed concrete is subject to the same limitations as to the interval between the adding of the cement to the aggregates and final placing as is the centrally mixed concrete, unless the aggregates are entirely dry. Under ordinary circumstances aggregates contain sufficient water to hydrate a large part of the cement. It is obvious that any one of the various types of truck mixers can be used for the transporting of ready-mixed concrete.

The general experience with ready-mixed concrete has been very satisfactory, but there are a number of problems which must be solved before all the advantages of this system can be realized. The cost of ready-mixed concrete is generally somewhat higher than what the contractor *thinks* he can produce concrete for on the job. This may be partly true because the organization producing ready-mixed concrete is obliged to have a great deal of money invested in plant and transporting equipment, but there is being produced better concrete generally than that produced on the job. The contractor very seldom has any idea of his concrete costs, but when he buys ready-mixed concrete just as he buys steel the cost is definite, and sometimes he is surprised what it amounts to. This surprise is often increased when he finds that the quantity required to fill the forms is greater than the cubical contents as given on the plans. Spillage, give of forms, and irregularities of the subgrade become items of importance when you are buying concrete by the yard. Shrinkage of the concrete in very large pours is also worthy of consideration, although the quantity supplied is usually sufficient in excess to offset this one-half to one per cent volume loss.

It may appear to be the function of ready-mixed organizations to supply the concrete to the job, and that of the contractor to place it. In some cases the ready-mixed concrete organizations are doing both, but in most cases they are helping the contractors to work out methods of placing which will cause the least delay. The best procedure is to provide a hopper into which the truck can dump, and from which the concrete is distributed by buggies to the forms. On road work it is frequently possible to pour directly into place. Close co-operation

is needed between the job and the ready-mixed plant so that changes can be made in the mix to suit the requirements of the job and to prevent delay or loss of concrete. Long delays between batches will naturally cause loss due to men being idle, and may result in damage to the concrete in place. Thirty minutes between batches poured in the same form is a reasonable maximum limit.

The truck mixers are large mixers taking batches of from two to five cubic yards of concrete, and they require, therefore, a longer time than usual in order to get thorough mixing. Improper loading of these trucks also makes it difficult at times to get proper mixing throughout the batch. A mixing time of at least five minutes is a reasonable requirement for truck mixers, and it is preferable to have part of this mixing done in transit. The vibration from the road will aid in the mixing.

PRODUCTION OF UNIFORM CONCRETE DEMANDED

Most commercial ready-mixed concrete organizations have as their aim the production of uniform, high quality concrete, and their equipment and control methods are as good or better than the best used in large job plants. They need this equipment and control because of the demand for concrete of many different kinds. It would seem proper to remove many of the present restrictions in regard to the proportions of materials, and specify only the important characteristics desired. This would allow the ready-mixed concrete organizations to make concrete as economically as possible, and would result eventually, as competition increased, in the passing along to the contractor of some of the saving. If concrete having a strength of 2,000 pounds per square inch is desired, with a 6-inch slump, why should that not be specified and a further safeguard be provided by requiring a certain number of tests on the concrete as placed? If a definite cement content and consistency are desired, that may be specified as well as certified statements of the quantities in each batch and check up from time to time on the measurements at the plant. I believe the future holds great possibilities for ready-mixed concrete, particularly because of the increased difficulty of construction in congested parts of large cities, and the demand for concrete of known quality. A logical development would be for the ready-mixed concrete organizations to take over the placing as well as the supplying of the concrete, so that concrete could be purchased for a unit price in place or erected, just as steel is today.

OF GENERAL INTEREST

THE PORT OF HAMBURG

*By Frederic H. Fay**

EDITOR'S NOTE. — *Mr. Fay has recently returned from a trip to Europe, on which he made inspections of a number of British and Continental ports under official guidance. Through courtesies extended by the German Foreign Office, at the request of the American Ambassador, he had an unusual opportunity to investigate conditions at the Port of Hamburg.*

Hamburg lies on the Elbe River at its confluence with two smaller streams, the Alster and the Bille, some 62 miles above the deep-water estuary where the Elbe discharges into the North Sea. As early as the beginning of the ninth century it was a fortified place, far enough inland to be safe from hostile incursion, yet having access to the sea as well as water communication with the interior. Its hinterland, from the earliest days, included the Elbe country up to Bohemia, together with the Havel and Spree districts, and territory reached by smaller tributaries of the Elbe. Because of its favorably protected situation it has been a trading port of importance for nearly a thousand years. Inland water transportation by the Elbe River and its tributaries became firmly established centuries before the development of highways or railways, and it has been maintained

to this day as an important element of Hamburg commerce. It has been augmented by river improvement and the building of canals, until at present there exists a network of inland waterways connecting Hamburg with Kiel, Lübeck, Stettin and Danzig on the Baltic Sea, reaching Berlin and other important centers of northern Germany, and extending across the German borders into Poland and also to Prague, the capital of Czechoslovakia.

Barges up to 1,000 tons' capacity are used on the major portions of these water routes. Bulk commodities, such as coal, ore, mineral earths, timber and building stones, constitute about 75 per cent of the freight traffic of the German waterways.

In Germany as a whole, in 1924, about 21 per cent of the total inland freight traffic used the waterways, and about 79 per cent the railroads. At Hamburg, however, the proportion of inland waterway traffic is far greater. Of the hinterland trade to and from Hamburg that year (excluding ocean-borne trade) 45 per cent moved over these inland waterways as against 55 per cent by railways. Before the war the corresponding figures for Hamburg were 62 per cent water-borne, and 38 per cent rail-borne traffic. Authorities believe that in the near future the pro-

* Of Fay, Spofford & Thorndike, Consulting Engineers, Boston, Mass.

portion of water-borne traffic with the interior will tend to approach pre-war figures. Thus the problem of handling freight at the Port of Hamburg, where, roughly, half the movement is direct transshipment between ocean carrier and inland waterway barge, differs materially from that of most American ports, where the problem is one of trans-

ditions which must be met and solved in a way to best meet the special needs of that port. To a degree every port is a problem unto itself, and the facilities and methods found by experience to be best adapted to one port may not always be copied advantageously by another.

The fact that Germany, through the



FIG. 1.—VIEW OF SEGELSCHIFFHAFFEN, ONE OF THE SEVERAL HAMBURG BASINS

Shipping at the right is moored to two lines of dolphins in the middle of the basin

fer between ocean carrier and the shore. New York, with its extensive lighterage system, is the only American port at which conditions approximate those of Hamburg. This movement of freight over inland waterways rather than by rail is a condition found at many European ports.

Every port has its own peculiar con-

improvement of river channels and the building of canals, had developed its system of inland waterway transportation long before railways were built, has meant that in that country the inland waterways have continued to function, notwithstanding railway competition. All along they have had an important influence on rail rates. In this respect

conditions in Germany differ markedly from those in America, where, so far as a considerable section of the country is concerned, the railroad has been the pioneer, and only lately is the attempt being made to develop waterways as auxiliary service. Germany is handicapped by its lack of seaports on its own soil. The Rhine and its tributaries, the main artery for the waterborne movement of the commerce of southern and western Germany, finds its outlet to the sea in another country, — Holland. At the present time Ham-

port where seemingly insurmountable natural obstacles have been splendidly overcome, and the port has been developed to a point where it is an example of what a well-ordered port should be.

In the first place, it strikes one as perhaps strange that so important a seaport should be found so far inland on a river no larger than was the Elbe in its natural state. At the middle of the last century the 62-mile river channel had a depth of $6\frac{1}{2}$ feet at low water and 13 feet at high water. This chan-



FIG. 2. — A FLOATING DOCK

Of the many such docks, the largest has a lifting capacity of 81,000 tons

burg is the outstanding German port, and its commerce is greater than that of all other German ports combined.

Germany as a whole and Hamburg in particular are water-way minded. Already an important canal is projected from the Rhine to Hamburg to divert to that city much of the German commerce which now finds its outlet to the sea through the Dutch port of Rotterdam. Probably this canal will be built some day, but its construction is a costly undertaking, and German finances do not warrant building it at the present time.

Hamburg is notable as an inland sea-

nel has since been improved until today vessels drawing 32 feet of water regularly navigate the river up to Hamburg.

The shipyards at Hamburg have turned out some of the world's largest and most famous ships. Such vessels must be taken down the river in a lightened condition, however. In the case of the latest of these, the steamship "Europa" of 51,655 gross tons' register, it was necessary to use pontoons to further lessen her draft.

Before the war Cuxhaven, at the mouth of the Elbe, a part of the territory of Hamburg Free State, had been developed as a port of call for the largest

liners whose draft did not permit them to ascend the river to Hamburg.

The modern port of Hamburg is wholly an artificial port created by dredging basins out of the land and using the material for filling adjacent quays. At present the port development lies within an area about eight miles long and two miles wide, along the southerly bank of the Elbe. Up to about sixty years ago quay facilities were entirely lacking, and midstream transshipment of freight between ocean vessels and barges or lighters was the only method of freight transfer in use. The modern port, with its admirable system of quays and freight-handling equipment, is the work of the past thirty or forty years.

One feature which particularly impresses the visitor to Hamburg is that port development there has been carried out in an orderly, specialized and systematic manner according to a well-thought-out plan. Different basins are provided for different classes of shipping and for different uses, and the depths of water in the several basins vary according to the draft of the shipping using them. Since approximately half of the commerce of the port involves the direct transfer of cargo between ocean ship and canal barges, the basins are generally built of width sufficient to allow ships to tie up to rows of mooring posts or dolphins in the center, as well as to the quays alongside.

At no other port has such thought been given to the speedy and economical handling of cargo, and none is so completely equipped with modern mechanical devices for the handling of freight. To quote from a recent official publication * concerning the port:

Every technical innovation that seems likely to be of use is tested by the port authorities, but none is introduced un-

less an extended trial period has shown that it is specifically adapted to the peculiar requirements of the Port of Hamburg. Many a novel device and many a new idea owe their origin to the experience gained by the Hamburg port administration. The first electric harbour crane was built in Hamburg, and the twin crane, the triple crane, and — as far as Europe is concerned — the electric truck as used for quay operation were first introduced by the Port of Hamburg authorities. The aim of these and similar improvements was to eliminate every avoidable delay in working. Thus, for instance, the speed of the crane work has to be correlated to that of the work going on in the sheds in such a manner as to ensure the maximum benefit from both, and stoppages of work have everywhere been reduced to a minimum. It has thus been possible to gradually increase the efficiency of the work performed per man and per hour. It goes without saying that the output — like that of every big industrial concern — is constantly checked, and that statistical records concerning it are carefully kept. The ideal before the authorities is to utilise the available plant to best advantage and to keep abreast of the progress of the times.

HAMBURG FREE PORT

Hamburg is the world's outstanding free port. Since of late there has been discussion of the possible establishment of free ports in America, particularly at Boston, a brief description of the Hamburg free port may be of interest.

The term "free port" does not mean that ships or goods may enter a port free of charge, or that cargo entering the country through a free port is exempt from customs duties. At a free port a certain area of the harbor is set aside so that while ships or cargoes remain within the boundaries of the free port zone they are unmolested by customs. The particular economic reasons

* "The Port of Hamburg," by Wendemuth and Böttcher, 1927, page 90; from which, also, the accompanying illustrations are taken.

for a free port are to expedite the movement of transshipment cargo, to effect a speedier turn-around of vessels, and to avoid tying up capital in customs duties.

The development of the Free Port at Hamburg is the logical outgrowth of the peculiarly independent position which Hamburg enjoyed up to about fifty years ago when she became more

the municipality of Hamburg alone was 1,074,990. The situation at Hamburg is somewhat analogous to that which would exist at Boston if the Boston metropolitan district were severed from Massachusetts and set up as a State of the American Union. Unlike the Boston metropolitan district, however, the territory of the Free City of Hamburg is not contiguous. Some parts



FIG. 3.—DOUBLE CRANES ON AUSTRALIAQUAI

closely knit to the German Empire. The Free City of Hamburg, like Prussia, is a State unto itself, one of the Federal States of the German Republic. The Federal State known as "The Free City of Hamburg" covers an area of about 160 square miles. It comprises the four municipalities of Hamburg, Bergedorf, Geesthacht and Cuxhaven, as well as 28 rural communities. The population of the whole State in 1925 was 1,152,480, of which that of

are close to and some remote from the main city. Cuxhaven, for example, at the mouth of the river Elbe, is over 60 miles distant from the city, and the Free State includes two islands in the North Sea beyond the river mouth. A part of the Cuxhaven territory is included as a portion of the Hamburg Free Port. The Free City of Hamburg has always remained independent of Prussia, which surrounds it, and for centuries it has controlled the Elbe out-

let to the sea and has regulated its own commercial affairs. Upon the re-establishment of the German Empire, in 1871, Hamburg retained the right to remain outside the German Customs Union. The resulting anomalous position greatly inconvenienced the interchange of goods between the port and the hinterland. In 1888 Hamburg joined the Customs Union with her entire territory, except that occupied at the time by her port developments and certain additional area reserved for the future expansion of the port. The port has now outgrown the limits of the area established for the free port zone. The present port area of Hamburg is divided into two parts, — the free port, which is legally outside the German Customs Union, comprising the major portion of the developed harbor, and including all facilities for handling overseas commerce; and the lesser portion, which is within the German Customs Union territory where certain local and inland commerce is handled.

The adoption of the free port principle has enabled Hamburg to greatly accelerate the despatch of vessels. The latter are not subjected to any custom house examination on entering either the Elbe estuary of the free port area, nor are the goods carried by them liable to any customs dues. The ships are taken to their berths without any delay, and are at liberty to start their discharge at once. Although during their passage up the Lower Elbe they are passing through the area of the Customs Union, they nowhere come into contact with the shore, so that technically they remain abroad. The pilot taken on board is sworn in as a customs officer, and sees to it that the customs regulations are duly complied with. His presence is shown by the black and white customs ensign which is hoisted as soon as the ship enters the estuary of the Elbe. During the night a

green and white stern light is used for the same purpose. Once the goods have arrived within the free port they may be discharged, sorted and stored without the payment of any customs duty and without any customs supervision. They may, indeed, be manipulated in any way to which goods are usually submitted when they are in port. Raw materials may even be converted into semi-finished articles without paying the duty. This latter regulation has greatly promoted the development of the port into a center of the transit trade by sea, and has caused numerous industries to settle there in addition to the old established shipbuilding industry. The advantages they enjoy consist in the duty-free admission of the raw material, the duty-free exportation of the semi-finished products, and the saving of the cost of transport between the place of manufacture and the seaport.*

Goods are unmolested by the customs so long as they remain within the limits of the free port. The moment they pass beyond the free port boundary into German territory, however, they are subject to duty as at any other German port. This is true if they be taken even into the business section of the City of Hamburg, which is not a part of the free port zone.

Peculiar reasons have caused the existence of this free port. Hamburg has long been a port of transshipment of goods brought from distant countries by ocean vessels and destined to neighboring countries other than Germany, such as Denmark, Norway, Sweden and the Baltic States. In reverse movement, these same countries send some of their export products through Hamburg to distant parts of the world. If these countries were required to pay German customs duties on entering their goods at the Port of Hamburg, even though a rebate of duty were

* *Ibid.*, page 57.

granted when goods left the port, there would be much delay, inconvenience and unwinding of red tape, with possible international misunderstanding. Under such conditions Hamburg would undoubtedly suffer serious loss in this international transshipment business now done within the free port. However, all this is avoided, transshipment of goods of both foreign origin and for-

the wants of vessels coming to the port, and in various ways it has greatly aided the prosperity of the city. Thus the first function of the Hamburg Free Port is the receipt from, and the despatch to, various countries of cargoes not originating in or destined to Germany at all.

A second function of the free port is that of industry which is the outgrowth



FIG. 4.—COAL LOADING BRIDGES AND FLOATING COAL ELEVATORS

eign destination is cheapened and expedited, because of the unrestricted movement within the free port zone. The resulting economy and despatch have brought to Hamburg a vast amount of international commerce which she would never have handled except for the free port exemption from customs regulations. This international business means much to Hamburg. It furnishes employment to her citizens, business to her merchants in supplying

of interchange of foreign cargoes at the port. Much raw material requiring processing or manufacture before becoming ready for use in the northern European countries is brought to Hamburg from distant points. The city early took advantage of the opportunity to make a profit by herself processing or manufacturing much of this raw material before forwarding it to other near-by countries. Accordingly, when the treaty was concluded, which resulted in the ad-

mission of the Hamburg Free State to the German Customs Union, the right was reserved to carry on manufacturing within the free port zone. In 1925 there were, within the limits of the free port area, 151 industrial establishments occupying 562 acres of territory leased from the State and employing 25,363 workmen.

Shipbuilding, ship repair and allied industries are the oldest and most important industrial development within the free port zone. Other industries include the manufacture of chemicals;

There is also customs supervision of the harbor railway yards and of the gates by which land traffic enters and leaves the free port.

There is no residential area within the free port zone and all of the thousands of persons there employed must live outside the barricade. Since the free port area is on the south side of the river Elbe, and the municipality of Hamburg, as well as the contiguous city Altona, are on the north bank of the river, there is necessarily a heavy passenger movement across the river,



FIG. 5. — CUSTOMS BARRIER ASHORE

milling; ore crushing; fruit preserving; coffee roasting; malt, coke and wood manufacturing; wineries; cold-storage warehousing; and such industries connected with the foregoing, as bottling, boxing and bagging factories.

The German customs authorities keep a most watchful eye on the free port area, which is carefully guarded by high iron railings on shore and by floating palisades where the boundaries run across water spaces. These floating palisades are movable, and the principal water entrances to the free port area are left open during the day and guarded by the aid of customs' launches.

particularly during the rush hours of the morning and night. The only bridges across the Elbe are three immediately to the east of the free port zone and above that portion of the harbor devoted to deep-water shipping. One of these accommodates a railway line which serves both the free port area and other port territory, and two are for vehicular traffic. Ferry launches are the principal means of transportation for pedestrians. The Hamburg vehicular tunnel, however, is another facility connecting the municipality of Hamburg on one side of the river and the free port area on the other.

THE ELBE TUNNEL

Hamburg was a pioneer in the building of a vehicular tunnel, and now, a quarter of a century later, Boston is following in Hamburg's footsteps. Early in the present century the Elbe bridges were no longer adequate to meet the demands of the increasing traffic. The existing bridges are at low level, with clearance sufficient only for

with the Steinwärder industrial district of the free zone. It saves road vehicles — and, whenever the ferryboat services have to be temporarily stopped in consequence of ice conditions or very dense fog, pedestrians as well — a detour of $7\frac{1}{2}$ miles. For a half hour or so at morning and night, when pedestrian traffic reaches its peaks, vehicular traffic is excluded from the tunnel, which

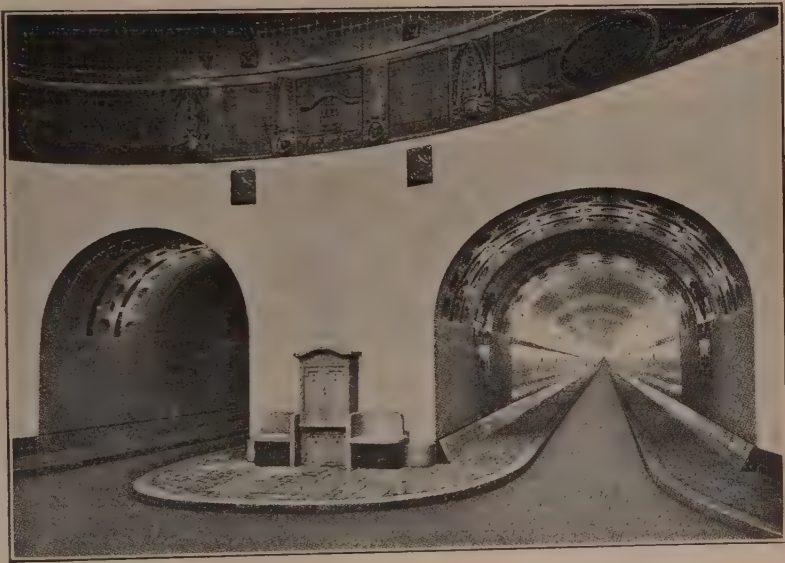


FIG. 6. — THE ELBE VEHICULAR AND PEDESTRIAN TUNNEL
View of a tunnel tube from the entrance

tow boats and barges running up river to the interior of Germany. For the needed new facility the projects of a high level bridge and an aerial ferry were considered and rejected. The decision was reached to augment the then existing facilities by the construction of a tunnel below the riverbed.

The Elbe Tunnel, which was opened to traffic in November, 1911, at a cost of about \$2,500,000, connects the north bank of the river at the St. Pauli Landing Stages, near the heart of the city,

is then used solely by pedestrians. The northerly, or city, entrance to the tunnel is at the foot of a steep river bank, and both entrances are located in areas that are intensely utilized. For these reasons it was practically impossible to construct inclined tunnel approaches; instead, the approaches consist of two vertical shafts, each 72 feet in diameter and 77 feet deep. Each shaft is equipped with six electric elevators, two of 10 tons', two of 6 tons', and two of 2.4 tons' capacity each. The two

last named are used for passenger traffic, and the other four for vehicles. The walls of the shafts are provided with staircases; the elevators occupy half the area of each shaft, the other half being required to transfer the traffic from them to the tunnel tubes. Above the road level the two shafts are surmounted by domed buildings whose large windows enable the daylight to reach the bottom of each shaft. One is impressed with the spotless cleanliness and the remarkably good lighting, not only of the shafts but also of the tunnel itself.

The tunnel is 1,470 feet long from shaft to shaft, and consists of two parallel tubes, one serving northbound and the other southbound traffic. Each tube has a roadway 6 feet wide, bordered on each side by foot walks $4\frac{3}{4}$ feet wide. Pedestrians use the tunnel free of charge; vehicles pay toll according to a fixed schedule. As the

tunnel leads from the customs area to the free port, special custom house facilities are provided at the Steinwärder entrance.

PORT CONTROL

The Senate of the State of Hamburg has complete control over all matters pertaining to the port. It delegates, however, the supervision of the functions of the harbor to several intermediate boards or committees, which are responsible on all matters allotted to them. The success of the Port of Hamburg is due to the fact that under public ownership and control, and, to a large extent under public operation, it has attained a high degree of unified development through efficient, far-seeing and non-political management. It is an example of port development and administration well worthy of study by engineers and all others who are, or should be, interested in port welfare.

PROCEEDINGS OF THE SOCIETY

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[October 20, 1930]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of fifteen (15) days from the date given.

RICHARDSON, COBURN MAURICE, Brookline, Mass. (Age 22, b. Mars Hill, Me.) Graduate of Groveland High School, and entered Northeastern University September, 1927. During co-operative periods has worked as instrumentman and draftsman for H. S. Freeman, consulting engineer, of Hartford, and at present is employed as chairman by the New York, New Haven & Hartford Railroad. Refers to *H. B. Alvord, C. O. Baird, J. W. Ingalls, K. D. Sylvester.*

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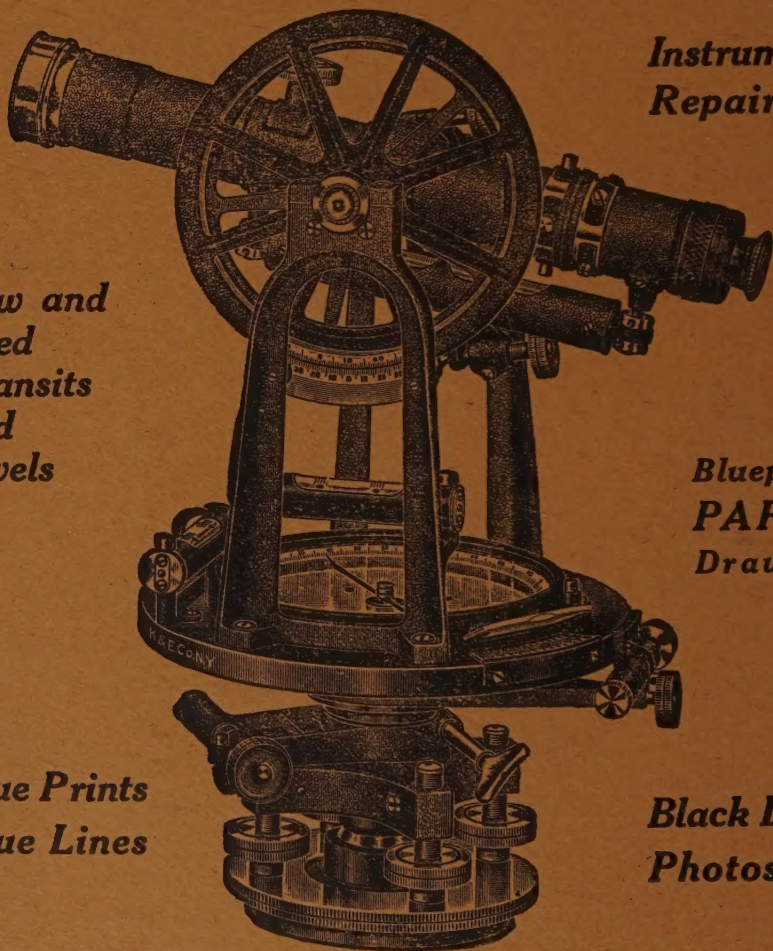
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